Notes-
Electrical Engineering I.

Notes
— of —
Lectures
— on —
Electrical Engineering
— by —

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ELECTRICAL ENGINEERING

Electrical Engineering the scientific aspect of the art of utilizing electricity, whether generated by Static machines studied by Franklin and Gilbert or otherwise:-

Effects reproduced by:-

Plante	Batteries
Tesla + Thompson	Dynamos
Lodge	Influence machines

Batteries invented by Volta

Improved by Grove, Bunsen + Davy

Dynamos invented by Pacinotte, Faraday + Gramme.

Improved by, Siemens; Edison Brush Weston &c

Whether used as: Light, Heat, Chemical Action or Mechanical energy

In every case we must have a <u>source of electricity</u>: Battery, Dynamo, Thermo-pile, &c.

<u>Means of Transmission</u>: Wires or Storage Batteries.

<u>Translating devices</u>: Lamps, Resistances, Magnets, Electrolytic baths, Dynamos &c

Whatever the source and translating device, we must have means of transmission.

Storage Batteries secondary means of transmission.

Primary means are <u>wires</u>. Name given to threads of metal produced by drawing <u>cold</u> metal through draw plates.

All wires offer an obstruction to continuous currents entirely due to resistance expressed in ohms

Due 1st to material
2nd to size & length

To alternating and pulsating currents also to inductive resistance:

Due 1st to material of wire
2nd to " insulation
3rd " location of circuit.

Resistance due to material:

1	Silver	= 103.	7	Tin	15.45
2	Copper	100.	8	Soft Siemens steel	12.
3	Gold	78.	9	Platinum	10.6
4	Aluminium	34.2	10	Lead	8.88
5	Zinc	29.9	11	Nickel	7.89
6	Swedish iron	16.	12	Antimony	3.88

Of these, available for wires:- { Copper, Iron, Steel

Conductivity of copper $6\frac{1}{3}$ times that of iron hence used where cost allows.

Tensile strengths

Copper wire		50,000 □"
Cast steel wire	up to	300,000
Bessemer steel wire	" about	90,000
Iron wire		50,000

Inductive resistance due to material
proportionate to magnetic permeability
Copper = none
Iron = great
Hence copper is used for carrying
great currents ... always
ditto small currents ... when cheap
" pulsating currents ... always.
Iron used for carrying telegraph
or other small currents when cheapest.
Steel is used on long spans
Alloys used in conducting where strength
is required: Copper with
Tin
Aluminium
Silicon
Phosphor Bronze

$Cu + Sn$ Strongest U S B $\begin{matrix} Cu & Sn \\ 82 & - 18 \end{matrix}$

1 to 3% produces increase of
strength amounting to as much as
much as 80,000 lbs #10 B & S. W.
Conductivity 1% = 45%
3% = 35%

Phosphor Bronze not over 35%
Composition: 4 to 5% Sn.
1/10 % P.

Silicon Bronze
made by M Weiler, Angoulême
Incorrectly containing no Si.

Copper	40,000 lbs	conduct.	100
Si. Br.	64,000	"	96
"	108,000	"	34
Phosphor	102,000	"	26
Iron	51,000	"	16

American Copper

Copper	50,000 lbs	
Iron	45000	
Si Br.	80,000 "	45%

Aluminium Bronze
Same properties as Si Br. but more conductivity

All Brass

Cu.	67-71
Zn	31¾-25½
Al	1¼-3½

Very strong and good conductivity
Delta Metal
Zinc, Iron and Copper with Phosphorus resists acids bad conductor.
Tobin Bronze
Deoxidized Bronze
Hardened Copper
Alloys for resistance
German Silver
Manganese Bronze
Platinoid (G. S. with Tungsten)
Platinum Silver.
German Silver

Cu.	60 or	57 or	56 or	50
Ni.	8 "	12.5 "	20 "	30
Zn.	32 "	30.5 "	24 "	20

Conductivity
12 times Cu; 16 times Cu; 20 times Cu; 40 times Cu.
Alloys are used in Resistance on account of small Coefficient of temperature.

Wire manufacture

Copper resistance increases ⑦
per t°, C.

$R^{t°} = r(1+.00388 t°C)$

German Silver

$R^{t°} = r(1+00044 t°C)$

Platinum Silver

$R^{t°} = r(1+00031 t°C)$

Platinoid

$R^{t°} = r(1+00021 t°C)$.

Manganese Bronze

$R^{t°} = r$ or smaller.

Platinum Silver

Silver −2; Pt. −1.

Manganese Bronze

5% Ni; 15% Mn; 80% Cu; gives a resistance 40 times Copper.

Platenoid: German Silver with small amount of Tungsten.

Production of wires.

Wire-bars are the first shapes used by wire mills; at present

Mälinats

mills are using bars 4" Square by 2' long, weighing about 135 to 250 pounds.

Formerly bars were rolled at from two to three heats, in twenty to fifty pound pieces; handled through each pass separately.

The various materials require different treatment.

Iron and steel are both stiff capable of being welded with less care in regard to finning and scratches.

Cu + Zn

Copper and hot maleable bronzes being incapable of welding must be protected against the action of the guides and scars in the rolling.

Cu Zn

Brass and many bronzes must be generally rolled cold and in flat strips, to be sawed into square rods and then drawn.

Modern Rolling Mill.

Roughing Train

Belgian Train.

Modern Rolling Mill: consists of (9)
Roughing train; which is three rolls geared together, the center one being driven while rods are passed by two men back and forth through alternating square and oval grooves, producing a rod about one inch square and twenty feet long, being as long as can be drawn out on the floor each time, it is then put in a continuous mill, passing from one pair of rolls to the next without changing its direction.

These rolls must be belted together and liable to break down.

The Belgian train has rolls all on one shaft, the rods pass from square to oval, in repeaters, from the oval to square, are caught by "stickers in" and guided. In both cases the slack passes down long inclines. The de-

annealing

fect of this system is great scaling, as much as 7%. 10

Brass rolled while hot, smoothed cold and sawed into bars.

Many materials scarred in this process never can be remedied. A sliver in a wire means defective rolling, rods should be examined for fins which may be covered up in the drawing.

Some become evident only through the use of the wire.

Wire rods so produced must be annealed by heating to red heat and cooled. This is done in pots 7 feet high by 60" in diameter, holding about 5 tons, and are heated by coal or oil. When all is at a cherry red the fire is drawn and the whole is cooled. In this process the oxygen of the air scales the wire covering the surface with a

Using Drawing

brittle hard oxide which, if not cleaned off will fill up the draw plates and scratch the wire.

This scale must be cleaned off with hot acid and the wire covered with a coating of lime or flour paste which will prevent further oxidation by the air, also acts as a lubricant in drawing.

Wire drawing

After annealing and cleaning the rod is drawn into wire. Drawing is a process of passing a rod through a steel or iron die, reducing the size and making it exactly round.

The rods are thrown upon "swifts" & pulled through the die upon wire blocks which are so arranged as to feed upon the lowest point and to slip up the wire as fast as it is drawn.

Steel Trust.

wire is drawn at the rate of three to seven hundred feet per minute according to size.

Wire is more or less often annealed and cleaned.

Copper is not annealed at all until drawn to finished size.

The effect of drawing seems to roll down the outside and stretch the centre, consequently the smaller a hard drawn wire, the greater its strength per square inch.

The experiments of H. Allen show steel in strand 28 tons per square inch; 28% elongation: rod increased 14%; with decreased elongation; rod increased 14%; with decreased elongation and the wire showed 44 tons per square inch

U.S. Ordnance Board, gives:—

Wire Bar Tensile Strength 73,500# (13)
" " elongation 0.34
" " reduction in area at break 54.6%
Wire from same billets gave:-
Tensile strength 160 550
Elongation per inch .009
Reduction in area at rupture 16%
Wire is drawn through cast iron dies with reamed holes; also steel dies with holes hammered up and reamed.

Cast iron dies are used on large sizes and in rough drawing; steel, for accurate finish and high polish on the wire.

Ordinary iron wire varies as much as .003 of an inch from gauge; accurate or copper varies not over .001 of an inch generally, or 1% of the diameter.

During the drawing different tempers may be produced by annealing at various stages of the process.

For the finest finish and most accurate drawing, wire should be annealed just before finishing. For great strength the smallest possible amount of annealing is preferred.

Square and various other shaped wires may be drawn in the same manner but the increased cost of making and maintaining the dies is excessive.

Wire may be drawn in this manner up to $\frac{1}{2}$" in diameter but larger than that the shape is changed too much by winding on a 30" drum hence larger wires must be drawn straight or made from small ones on a strand machine.

Wire Gauge

Birmingham

Brown & Sharpe

Edison

Copper wire is finished by drawing hard. Iron wire must be annealed cleaned, - passed through a bath of molten zinc, which galvanizes it.

When so finished the wires must conform to specifications; for copper to Am. Bell Tel.; iron Western Union and English.

Wire gauges are used to determine stock sizes.

The Birmingham is an arbitrary gauge used in iron wire, brass &c. Brown & Sharpe, beginning with .005 No 36, advances in arithmetical progression; used in copper wire; the even numbers are kept in stock. The Edison guage; numbers represent the number of circular mils area in even thousands.

Note the circular mil is the square

Stranded wire

This gauge would have been an excellent one had it been adopted but those in use, already filled its place.

The largest size wire in use in any gauge in use is the Edison No. 360 or 600 mils diameter. Larger than this, drawing is not a practical thing. Strands are used for larger wires and in general for all large sizes of great length.

Perfect strands have centres of three or seven wires. Layers above the first increase six wires for each layer.

It is possible to lay up a strand of any number of wires, thus: (over)

of the diameter expressed in mils; used as an expression of the area of a wire; area $= d^2 \frac{\pi}{4} = d^2$ constant.

Calculation

1 -	2 -	3 -	4 -
6 - 7	8 - 10	9 - 12	10 - 14
12 - 19	14 - 24	15 - 27	16 - 30
18 - 37	20 - 44	21 - 48	22 - 52
24 - 61	26 - 70	27 - 75	28 - 80
30 - 91	32 - 102	33 - 108	34 - 114
36 - 127	38 - 140	39 - 147	40 - 154

To determine a strand of any given size divide the area in c.m. by the number convenient to lay; extracting the square root, gives the diameter. Or, divide the area in c.m. by the area of the wire you desire to use and the result will be the number to lay up.

Calculations in various gauges
Given sizes in mills:-

1st circular mills $= d^2$
2nd Area $= d^2 \frac{\pi}{4}$
3rd Weight per 1000 ft. or per mile
Specific gravity 8.9
Water 62.425 per cu. ft.
Copper 555.5825 cu. ft.
Copper per □" x 1' = 3.855·1 [illegible]

Insulated wire

for weight per 1000 feet.

$$W = \frac{\text{wt. per } 1'' \times 1'' \times 1000}{1{,}000{,}000} \times \frac{\pi}{4} \times d^2 (\text{in mils}) =$$

$$.00385 \times .7854 \times d^2 (\text{in mills}) =$$

$.003030231159222 \times d^2$ (in mils) for weight per mile multiply by 5280.

4d; Resistance

1 mil foot at 0°C = 9.72° B.A or 9.612 legal ohm. Resistance of wire = $\frac{R \text{ mil ft } t^\circ}{d^2 \text{ mils}}$

Strands have 3% greater weight than the component wires laid straight hence 3% less resistance but the area should be taken as giving the resistance.

Diameter of any strand is found by laying out, and counting the number of wires across the strand.

Insulated wire — Henry, in 1830, experimenting with magnets and bells, insulated his own wire with calico. With the introduction of the telegraph by Morse it became necessary to make regularly insulated wire. Machinery for making bonnet wire and corset wire

Starting effect

was called into requisition - wire for magnets was wound, while for lines, a braided wire was used. With the introduction of the electric light, in about 1879, high potentials were used at once in arc lighting, and it became necessary to insulate the lines.

Annunciator wire wound with cotton and paraffined, and office wire braided and waxed were the first wires available.

Lack of knowledge of the heating effects occasioned badly proportioned circuits, and hence fires which were carried by the inflammable wax of the covering. On this account, the insurance companies determined a set of rules for running circuits, and demanded a non-inflammable covering. This resulted in what has been called "underwriters wire".

A covering of braided cotton saturated

Weathering.

with white paint; paint supposed to be white lead and oil, but as applied is largely zinc oxide and barytes. The reason: zinc produces a whiter finish.

Insulated wire should never be used out of doors. Bare wire is better for such purposes. Insulated wire is excellent material for unconcealed indoor work in dry places. It matches white walls better than anything else. It is going out of use because it wears through. It has the undoubted advantage of not burning, but readily absorbs moisture. It has grown into decided disfavor to the extent of being called "undertakers wire"

A wire more expensive but more satisfactory as an insulator is "weather-proof"; a double or triple braid saturated with a mixture of

Insulation material

asphaltum, ozocerite and petroleum residium.

Triple braid is the best not only on account of greater thickness but also on account of manner of manufacture. Triple being made by running twice through the hot pots thus more thoroughly saturating the yarn.

Triple is useful for pole lines and in damp places but not wet places.

The asphaltum compound is a non-absorbent of water and a good insulator, but nothing can saturate a yarn to such an extent as to prevent a further absorption of water.

Asphaltum itself is too liable to the action of heat to be used alone.

Residium is liable to oxidation and being rendered brittle.

Resin or coal tar makes insulation

run at all temperatures and is very liquid when hot.

Paraffine is very light, does not readily mix with other waxes; prevents filling of fibres by the heavier waxes.

Ozocerite has a high melting point. Paraffin taken from the earth mixes better and aids the polish.

Polish is to prevent the adherence of sleet and slime.

Wire should have little cotton and much wax; the cotton braided as loosely as possible except the outside which should be close and hard.

Such a wire will produce a pole line that will have a resistance of $\frac{1}{2}$ Megohms per mile in bad weather. No insulation tests should be asked of the manufacturer as the wire will absorb water and it is only a matter of the

Wire manufacturers

time of breaking down. In purchasing wire, prices should be figured by the pound rather than the foot and the requirement made that the feet per pound as represented by the seller should be within 5% of being correct.

Wires manufactured by:—

American Electric Wire Co., Providence, R.I.
Ansonia Brass Co., Ansonia, Conn.
Benedict and Burnham
H.B. and H.
A.F. Moore.
Roeblings,
Washburn and Moen,
Simplex Co.,
Wallace and Sons
Standard Under Ground.

Cowles wire of Ansonia is an Underwriters with outside finish of weatherproof, K-K of H.B. and H., the first of such wires. Shield Brand, Ansonia

Electrical Co: Wallace and Sons, Canvas Jacket.

American Circular Loom Co., made with straight threads about them finished with same compounds.

Duplex Wire, made by braiding several wires.

Wire that is made by saturating cold in solutions is to be avoided. The best wire is made by hot solutions.

Reason: The former is too porous on account of the evaporation of the solvent. The latter is more solid but is liable to be a poorly saturated braid when imperfectly made.

Salamander Wire, made by Washburn and Moen is a rubber covered wire with a coating outside of a non-conductor of heat which serves the purpose of radiating the heat and preventing

Rubber, vulcanization

the ignition of the wire from over heating from within or without. It has not been well tested as to durability. It seems brittle and is liable to be cracked if not carefully handled.

Rubber Insulation :— Rubber is a gum exuded by trees in the forests of South America and Africa. Probably the best is called Para, coming from the Amazon valley and cured by smoke

Madagascar, cured by admixture of an acid juice, is a hard gum like Para.

Guayquil, also acid cured, which with African Ball and others ranks as inferior.

As imported it carries stains, dirt etc which must be removed by mastication, a process of grinding between rollers. When finished it comes out in perforated sheets full of water

which must be thoroughly dried.

From 1830 to 1850, attempts were made to use rubber in this state or cut in strips and applied either spirally or longitudinally.

When in this pure state, rubber joins together readily when cut, if clean. Cables so made were consolidated by pressure or passing through warm water.

Experiments made on such a case proved: 1st Difficult to make perfect. 2nd In air the rubber would oxidize to a brittle resin. 3rd In water it would absorb 20% of its weight of pure water, and about 3% of sea water in 300 days. 4th Jointing was a very uncertain operation. These reasons made it necessary to abandon this method of manufacture for the employment

vulcanizing

of vulcanized rubber.

Vulcanization is a process of changing the properties of rubber by mixing it with from 10% to 50% of sulphur and heating it for about two hours at a temperature of 250°F.

If the sulphur does not exceed 20% this process makes the gum more elastic and not capable of permanant stretching.

The pure gum is brittle at 0°C.; the vulcanized is not.

The vulcanized does not oxidize in the air. It does not absorb more than 3% of water on continuous immersion while the pure gum seems to absorb indefinitely.

At present rubber covered wires do not use all pure gum, but have a mixture of whiting, zinc

oxide, litharge, barytes, ground as
asbetos, substitutes and covered rubber.

Recovered rubber, or Rubber Shoddy is obtained by dissolving all vegetable or animal matter, such as cotton or wool in chloride of zinc. Then dissolving out the sulphur by sulphuric acid. This process makes the best substitute for rubber.

In some cases it produces a gum hardly distinguishable from pure Para, as where unvulcanized rubber boot clippings are used. Other substitutes are mainly Linseed Oil boiled with Litharge to oxidize it as completely as possible. This process produces a very tough gum.

All of these compounds tend to make the rubber brittle in character after long use.

The mixtures of earthes and ox- (29)
ides should be so finely ground as
to show no particles to the naked eye.
It should not be made of oxides easily
reduced, or containing free metalic
elements - such as lead.

When 20% to 50% of suphur is
used hard rubber is produced and
is not used to a great extent in in-
sulating wires, as is not flexible.

Rubber covered wires may be:-
1st.- Plain, as American - Cresent - Safe-
ty - Okonite - Kerite.

Safety being simply a com-
-pound of rubber applied directly
to tinned copper wire. Copper is tin-
ned to prevent action of sulphur
on the wire.

Okonite is a compound of rub-
ber hairing, a small per cent of
paraffine applied in strips and

and pressed on by wheels, and vulcanized in a covering of tin to make the rubber compact. It is made in two grades, the first having one layer; the second and the best has three layers of rubber applied before vulcanizing.

Kerite is supposed to be a mixture of rubber and linseed oil, discovered by Day in experimenting on vulcanized oils. It has been much used by the telegraph companies in short cables across rivers. The experience so gained makes this company one of the best for such.

Crescent, Safety, and American are all good plain rubber insulators.

All of these coverings may be

obtained with either a braided or taped covering for protection against abrasion, which not only protects the wire, but also insures solidity in vulcanization, as it prevents the rubber from swelling up and becoming porous.

2nd- Cored, as Bishop - Grimshaw- Habershaan- Crescent. A core composed of rubber mixed with whiting or zinc oxide without sulphur is applied next to the wire and over this a covering of regularly vulcanized rubber.

The object is to protect the wire against the action of the sulphur. Secondary, and perhaps the most important is that it necitated two operations in manufacture, and gives a wire surer of being perfect.

Best of all of these wires is

Hooper's core, which is composed (32)
of three layers: first, one of pure rubber in a spiral layer, then the white compound, and over it a vulcanized rubber with tape.

Bishop is the best made in this country.

Habershaw - Grinshaw - Crescent are all about alike. Good when well made, which must be ascertained by careful inspection, including tests of every coil when good insulation is needed.

In this country little attention has been paid to the thickness required for different voltages, as there has been little work using more than one or two thousand volts; but in England the Board of trade has specified that every high pressure conduct-

or shall have at least $\frac{1}{10}''$ insulator, and that where the pressure exceeds 2000 volts, the insulation shall have the thickness expresed in inches of voltage divided by 20000.

This is burdensome thickness on small wires, and it was proprosed to substitute for it, this: The insulator to be not less than 1/7 the diameter of the conductor where the potential does not exceed 2000, and a proportionally greater thickness for higher voltages, and that the insulator must measure 1 meghom per mile per volt after immersion 60 hours in water at 60° F.

All rubber is apt to crack when subjected to the elements, when

under a bending stress.

Test of this property is most valuable but requires at least six months to complete

Statements of the manufacturer should not be relied upon if it is possible to test; but at any rate inspection should show, 1st, the wire should be capable of bending around twice its own diameter, without opening the braid or tape; 2nd, the wire should be capable of bending around its own diameter without breaking the rubber; 3rd, when cut the wire should show no fibers or lumps of foreign material; 4th when immersed for 60 hours in water at 60° F. it should show perfect insulation up to the standard

of specification

Wires of inferior rubber, or shoddy showing fibers should not be employed, as they are more harmful than a good weatherproof, since they are not so solid, and give an unwarranted appearance of safety.

Submarine Cables.— Short made of vulcanized rubber.

For long cables there seems to be too much uncertainty in the various paocesses of manufacture. Joints must be made by vulcanizing new stock to old, requiring one hour and a half. Defects must be repaired in the same manner. Process too tedious and uncertain. Experiment has shown the best material to be pure Gutta Percha.

The juice of the Isondra Gutta from Singapore only used.

European firms of ~~Siuemers~~; Felton and Guilleme; Silvertraum have agents buying up all on the market. Only job lots come to this country and are bought up by Bishop Gutta Co. latter have only made short cables.

Gum is worked up by shredding in hot water and pressed on wires through dies.

It is necessary that wire should be in the center of a perfect insulator closely stuck to the wire to prevent absorption of water.

The gum is laid on in three layers stuck to the wire and to each other by Chatterton compound,

which is Stockholm tar 1, Rosin 1, Gutta Percha 3.

Tested by immersion in water by five minutes electrical tests after 60 hours.

It is then placed in tanks and a pressure of 8000 lbs per square inch applied. Tested while under pressure, and after the pressure is relieved, the core so made is composed of 7 wires about $\frac{1}{10}''$ in diameter and insulated to $\frac{1}{4}''$ to $\frac{1}{3}''$.

Stranded conductor is used to reduce liability of breakage.

When core is completed, it is wrapped with three layers of jute tanned to prevent decay, and around it on the bedding of jute are laid galvanized iron wires to protect it against mechanical injury.

This is run through a coating of (38)
asphalt and sand, with jute well impregnated with asphalt and tar.

Underground Cables— Cables of the type of submarine cannot be laid, because when dry the rubber or gutta percha become oxidized and brittle. When laid in wet ground there is too great liability of action from vegetable and animal acids.

Therefore, underground cables are not only perfectly insulated, but also carefully protected by a metal covering.

Edison and Ferranti use iron pipes, but this must be made and laid in short sections. This is an advantage to the Edison company where high insulation is not required; but even here break downs are not

as unfrequent as might be desired.

With greater care, as in the Ferranti mains, a perfect insulation can be secured, but at greater expense.

The favorite method both here and abroad is to cover the cable with lead pipe. Lead is laid over the ordinary insulation and all kinds of rubber cables made.

There are two other important types: 1st, Paper. Many layers of paper are laid separately upon the conductor, making a hard compact covering which is carefully dried and saturated in an insulation compound. Compounds used are generally a a mixture of rosin and rosin oil, or paraffine, or cotton seed oil and rosin. Over this a lead coating is pressed, either

TABLE showing Conductors to be used under various conditions.

Part 2

Reference No.	Remarks
1	Not allowed.
2	Clear Spaces
3	Through trees
4	On glass insulators
5	On porcelain knobs
6	In porcelain cleats
7	In wood cleats
8	In insulating tubes
9	In wood mouldings
10	Without further precaution
11	If necessary
12	Below 350 volts
13	Above 350 volts

TABLE showing class of Conductors to be in various positions. } #1

Description of Conductor.	Position.							
	Open Air	Dry Rooms	Damp Rooms	Concealed under floor or walls	Rooms containing gases or vapors	Under Water	Under Ground	In Conduits
Bare Wires	2-4 3-1	1	1	1	1	1	1	2-4
Underwriters	1	2-5+6 13-1	1	1	1	1	1	1
Double Weatherproof.	12-4 13+2-4	2-5+6 13-1	12-4 13-1	1	1	1	1	1
Triple Weatherproof.	13-4	13-5+6+8	12-4 13-1	12-8 13-1	12-4 13-1	1	1	1
Plain Rubber	13-4 3-1	13-5	12-5 13-4	13-8	12-5 13-4	11	1	2-5
Taped or Braided Rubber	13-4	13-5+	12-5 13-4	13-8	12-5 13-4	11	1	2-5
Taped or Braided Cored Rubber.	13-4	13-5+9	12-5 13-4	13-8	12-5 13-4	11	1	2-5
Gutta Percha Armed	1	1	1	1	1	10	1	1
Rubber Leaded.	10	9	1	8	1	11	1	11
Paper Leaded.	10	9	1	8	1	11	1	11
Leaded & asphalt'd	10	9	6	8	6	11	11	10
Fibre Leaded.	10	9	1	8	1	11	1	11

by drawing lead pipes through dies or by compression in a hydraulic press.

This cable has the disadvantage of lack of flexibility of the paper which is likely to crack on too short a bend and and leaving a space free from air, cause a geissler vacuum of conducting power.

Non saturated cables are not so well adopted to high voltages as saturated; for although the insulation measures higher, yet the fibers are likely to carry current by electrification.

2nd, Fiber Cables:—Made of cotton or jute laid on in opposite layers, then thoroughly dried and plunged in a hot compound. Standard underground use petroleum residuum. American Electrical Works and Western Electric Co. use paraffine. Fatham and Co. use cotton seed oil and

rosin. Roeblings use rosin and rosin oil. (41)

Calculating Lines — Wires already described; will be taken us further as we specify use, but the various styles of wires and insulation always to be borne in mind.

Have already stated that losses came from resistance of wire which is always present.

Guage numbers give, by the formulae, the resistance per 1000 feet which is in cables.

To calcute a line we need to know;
1st, the E. M. F.
2nd, the current carried
3rd, the loss in E. M. F. allowed
4th, the length of the circuit, which means the total length. Then by Ohm's law;

$C = E/R \therefore R = \frac{E}{C}$. R for a line =

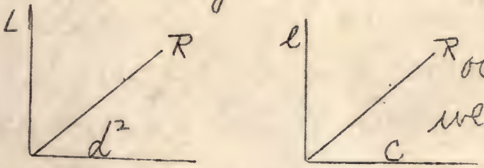
$\dfrac{e\,n\%\text{ total }e}{\text{total }c}$ } Then R per 1000 ft

$\dfrac{R\text{ of line}}{\text{length in 1000 ft units}}$

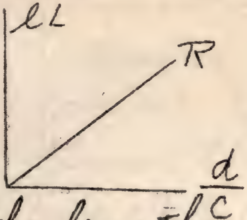
We have already seen that R per 1000 ft. $= \dfrac{R\text{ mil ft}^{\circ} \times 1000}{d^2}$ or $R = \dfrac{L \times 10.65}{d^2}$ ∴ R per 1000 ft $= \dfrac{10.65 \times 1000}{d^2}$ or $d^2 = \dfrac{10.65 \times 1000}{R\text{ per }1000\text{ ft}}$ or $d^2 = \dfrac{\text{length} \times 10.65}{R\text{ of line}}$

This gives diameter accurately, but as tables give the resistance per 1000 ft. of all available wires, therefore, this figure is whatever we require.

Now we have seen that $R = \dfrac{L}{d^2} \times 10.65$ in any wire and R of line $= \dfrac{e\,n\%\text{ of total }e}{\text{total }c}$ ∴ $\dfrac{L\text{ of line}}{d^2} \times 10.65 = \dfrac{e\,n\%\text{ of total }e}{\text{total }c}$ or L of line : d^2 :: e n % of total e : total c. Diagramatically,



Placing one over the other we have a graphic wiring table. The same result may



be obtained

This method of graphic calculations is useful in giving all the lengths, lights and sizes of wire on one sheet.

To use the method, a sheet of plane paper to be provided on which to lay out two rectangular co-ordinates. Then by a convenient scale of tenths, lay off volts = 10 divisions

1 volt = 10 divisions

20 ft = 1 division

1 Amp = 1 division

21076.5 C.M. = 10 divisions

Also lay off on latter scale B and S guages. Draw horizontal lines corresponding to the loss in volts allowed, and draw co-ordinates to these lines corresponding to the

current in amperes carried by the (44)
various circuits which will determine the lines of resistances. Continue these to the proper distances as indicated by absissae and the ordinates so determined will give the size of the wire required.

For various conditions of circuit and distributions, these measures may be varied, as in case short circuits are being determined lay out the abscissae

1 volt = 10 divisions
20 ft = 10 divisions

The ordinates–

10 Amperes = 10 divisions
21076.5 CM = 10 divisions

On long circuits at high potentials,

Abscissae –

10 volts = 10 divisions
200 feet = 10 divisions

Ordinates
10 Amperes = 10 divisions
2107.65 CM = 10 divisions
Determining Constants -
1st, currents and E. M. F. depend on system used and method of distribution.

Two important methods of distribution, all others, combinations of these two.
Series system, used always in arc lighting systems and sometimes in special incandescent plants.

In this the lamps are arranged one after another, the current passing one also passing through all the others; but each one offers a definite resistance and the E. M. F. must be raised to overcome the resistance of each additional lamp.

The current in such cases must

be kept constant, therefore loss
constant, and as the lamps are not independent, each must be arranged to be short circuited whenever it may accidently break the circuit.

In this case, the current is that required by each lamp, and the total E.M.F. equals the E.M.F. of each multiplied by the total number.

The multiple arc system is the system principally used for incandescent lamps. In this construction, the wires are run out parallel from the dynamo, and the lamps placed in the circuit by bridging across from one wire to the other. Here the potential is maintained as constant as possible at the dynamo. The current equals the current for each lamp multiplied by the number.

For arc lamps, the current is about 10 amperes. For incandescent lamps the average energy is 3½ watts per candle. Therefore, a 16 c.p. lamp requires 56 watts; a larger or smaller lamp more in proportion. Therefore, the watts ÷ by E.M.F. = c Multiple series is a system where the lamps are in series in groups around the mains. Thus each group requires a voltage equal to the E.M.F. of one multipled by the number in the group. The current equals the number of groups multipled by the current required by one lamp.

The Series multiple system is where the lamps are in parallel groups on a constant current circuit. The E.M.F. equals the E.M.F. of one multiplied by the number of groups; the current is the current of the lamp multiplied by the number in the group.

Both of these systems disadvantag-

series -

C = C of one lamp

E.M.F. = E.M.F of one lamp × no of lamps

parallel

C = C of one lamp × no of lamps

E.M.F. = E.M.F of one lamp

multiple series

C = no of groups × C of 1 lamp

E.M.F = E.M.F of one lamp × no in each gro

series multiple

C = C of one lamp × no in group

E.M.F = E.M.F. of one lamp × no of groups

eous because the breakage of one lamp throws the circuit out of balance. In the first case it throws the rest of the group out of the circuit; in the second, it increases the current in the others unless special devices are provided for taking up the extra current by throwing in a resistance or short circuiting.

Three wire systems devised about the same time by Edison and Hopkinson is a multiple series system without these disadvantages.

Two dynamos are connected in series with a third wire running from the neutral connection. When there are an even number of lamps on each leg, no current runs through the neutral; when the two legs are unblanced, the third wire takes up the extra current.

The E M F for the outside lines is twice that required for a lamp. The current of one lamp multiplied by half the number of lamps. The third wire then takes as ½ the size of either the outside wires.

3rd — The loss in E. M. F allowed

Three elements involved:—

a) Regulation of lights.

b) Carrying capacity of the wire.

c) Comparative cost of lost energy and interest on line plant.

Regulation:— In a constant current system, the regulation is always effected by an increase or decrease in the E. M. F. at the dynamo, as any change in the number of lamps or length of circuit produces a change of R which must be counterbalanced by a change in E M F. in order to keep c constant. This may be affected by a number of devices at

the generating station. The loss in volts, therefore, always determined by the carrying capacity and the ratio between interest on plant and expense of lost energy.

Multiple arc system and multiple series system and three wire system, the loss allowed is determined large by by the necessities for regulation. The E.M.F. must be kept constant at the lamps, and as the lamps are independent while the E.M.F. can be controlled by regulating devices only at the dynamo or at some part of the circuit. The futher regulation may be affected only by choosing the proper size of wire.

Ex. $E = CR$

$$\left.\begin{aligned} \therefore \text{ if } E\text{ loss} &= 5 \\ c &= 4 \\ R &= 1.25 \\ E \text{ at lamps} &= 50 \\ \cancel{E\text{ loss}} &\cancel{= 3.75} \end{aligned}\right\} \text{with 4 lamps.}$$

E loss 3.75

$C = 3$
$R = 1.25$
E at lamps = 51.25 } with 3 lamps.

E loss = 2.50
$C = 2$
$R = 1.25$
E at lamps = 52.50 } with 2 lamps

E loss = 1.25
$C = 1$
$R = 1.25$
E at lamps = 53.75 } with one lamp

3.75 volts, or increase of almost 10%. Therefore it is necessary to keep the loss at the smallest point possible for good regulation. The regulation may be further controlled by the arrangement of circuits which will be futher discussed when we speak of the length of the circuit.

For central station lighting, it is customary to allow 5% loss of E.M.F., 2% of which is mains leading from the generating plant to the building to be lighted; a further 2% in the risers or wires leading to the various floors of the building, and 1% in the branch circuits lead-

ing to the various lights.

In isolated lighting, the loss allowed is usually about 5%, similarly divided, but the amount of this loss is further limited by the carrying capacity and the cost of the energy lost in the line.

Carrying capacity of wire determined by the temperature allowable and the conditions under which the wire is run.

London Board of Trade allows 1000 Amperes per 1" where the current does not exceed 100 ~~Amperes.~~ volts.

The insurance companies of this country allow a rise of from 15° to 20° F. and give carrying capacities of the various wires as calculated from various experimental formulae.

Prof Forbes, in England, was the first to propose such a formula. Forbes's

formula is a theoretical one, and based (53)
only on experiments performed on small conductors and extended to large conductors. Solution due to Forbes is, let R = resistance in ohms of a cubic centimeter of the substance of the conductor; let E = the heat radiated per second from a square centimeter of surface, when the temperature of the surface is $1°C$ above the surrounding air. The radiation from the surface of one centimeter length of wire is $\pi D t E$ which must equal heat generated in one centimeter. Heat $= C^2R = C^2 \frac{R}{\pi\left(\frac{D}{2}\right)^2} \times$ number of units of heat in one watt $= C^2 \frac{4R}{\pi D^2} \times .24 \therefore \pi D t E =$
$C^2 \frac{4R \times .24}{\pi D^2}$ or $C^2 = D^3 t \frac{\pi^2 E}{R \times 4 \times .24}$

Therefore in heat by radiation, to keep all wires at the same temperature, D^3 must vary as C^2; but $R = .00001642$ ohms @ $0°C$, $E = .000168$ polished and $= .00032$ blackened.

These formulae give the true theory (54) of the problem, but as the constants of emissivity are those determined by by D. McFarlane in 1872 from balls and not from wires, it leads to questionable results in practice.

In 1889, A. E. Kennelly, of the Edison laboratory experimented, 1st, with wires in wood casings; 2nd, with wires suspended in a room; 3rd, with wires out of doors. Experimenting with wires ranging from ".0185 to ".119 and with currents reading 300 Amps. he obtained temperatures in all except the largest wires of 100°C. He found, among other things, as Prof. Forbes indicated from his theoretical formula, that the increase of radiating surface produced by insulating a wire allowed a greater amount of current to be carried by that wire in attaining a given temperature.

By plotting his curves, he observes (58)
that the temperature elevation varies
as the square of the current for any
given wire, which would be expected
when one reflects that the heat generated
varies as the square of the current,
and the conditions of radiation are
the same for any given wire. But
when he attempts to determine the elevation
of temperature due to diameter
alone, no simple law will cover the
complex case of varying radiation
and convection conditions. Therefore,
to ascertain the temperature which will
will be acquired by any wire of a
given diameter by the passage of a
known current, he has found it necessary
to adopt some certain temperature as the
allowable greatest temperature of the
wire. This figure he has taken from
the ~~(London)~~, rule of the London Inst of Elect.

Eng. which states that the conductors shall be so proportioned that double the current will not raise its temperature above 130°F. Now taking the mean temperature of the air to be 75°F this rule means, that double the current in any wire shall not raise its temperature more than 75°F., or as we have seen, the temperature varies as the square of the current, the normal running temperature shall not exceed 19°F. above the temperature of the air. 56

It is not possible to give exact formulae fore the temperature elevation in any wire, but a close approximation has been made as follows:–

$$C = 560 \times d^{3/2} \text{ if } d \text{ be in inches}$$
$$= 0.01775 \times d^{3/2} \text{ " " " " mils}$$
$$= 138 \times d^{3/2} \text{ " " " " c.m.}$$
$$= 4.375 \times d^{3/2} \text{ " " " " mm.}$$

and reciprocally,–

$$d = 0.0147 \times c^{2/3} \text{ if } d \text{ be in inches}$$
$$= 1.47 \times c^{\frac{2}{3}} \text{ " " " " mils}$$
$$= 0.0374 \times c^{\frac{2}{3}} \text{ " " " " cm.}$$
$$= 0.374 \times c^{\frac{2}{3}} \text{ " " " " mm.}$$

From these formulae the safe carrying capacity of any wire may be calculated for wiring in mouldings or conduits. This law shows that any such rule as 1000 Amperes per square inch is entirely inadequate, since for large currents it gives too small a wire, and for small currents too great a wire, as to carry 400 amperes the 1000 amperes per square inch gives a wire 503000 cm. while Kennelly's rule 640000 cm. To carry 40 amperes, the former calls for 225 mils diameter and Kennelly's rule 172 mils, connects at .504 mils 200 amperes.

This rule also points to the economy in using a number of small conductors in place of one large one, as for 500

amperes the rule indicates a dia- meter 928 mils, while for 250 amperes the diameter would be 585 mils. Therefore to carry 500 amperes we have:— (58)

1 conductor	2 conductors
1 of 928 mils	2 of 585 mils
861184 cm.	2 of 342225 cm.
	or 684450 cm.
	80% of 1 mm.

So in all cases where wires are run to their highest carrying capacity, it is better to run two mains where 2% of cost of one main will pay the extra expense of insulating and putting in the mouldings for another.

These deductions for wires in mouldings.

Proceeding to investigate the heating of wire when suspended in free air in a room, the losses may be divided into those of convection and radiation.

The radiation was found to correspond to the law of radiation announced

by Dulong and Petit in 1817:
$h = c(1.0077)^{\theta}\{(1.0077)^{t} - 1\}$ where
h = heat lost by radiation
c = constant depending on surface
θ = temperature of surrounding bodies
t = temperature of hot bodies in degrees Centigrade.

C was found by Kennelly to be equal to .05625; therefore h in watts per sq. cm. $= .05625(1.0077)^{\theta}[(1.0077)^{t} - 1]$

The convection was found to be approximately the same for all wires and may be represented by .00175 watts per linear centimeter per degree C above the air.

Furthermore, he found that a black coating on a wire would approximately double its radiating power and as a conclusion:

let d = diameter in cm.
t = given temperature elevation

γ = specific resistance at 0°C in ohms
θ = temperature of surrounding objects
m = coefficient of surface for radiation
$t + \theta = T$ = temperature attained by wire;
then resistance per cm. of length = $\frac{4\gamma(1+.00388T)}{\pi d^2}$ ohms ∴ energy developed per cm. by C amperes = $\frac{4C^2\gamma(1+.00388T)}{\pi d^2}$ watts per cm. The heat convected = $.00175\,t$ watts per cm. The heat radiated = $dm\pi \times .0687[(10077)^t - 1]$ watts per cm. where $\theta = 26°$ C., or if radiation = R_t — $.0687[(1.0077)^t - 1]$ the total radiation will be equal $dm\pi R_t$; equating gains & losses, we have $\frac{4C^2\gamma(1+.00388T)}{\pi d^2} = .00175 + dm\pi R_t$ ∴ $C = .886d\sqrt{\frac{dm\pi R_t \times .00175t}{\gamma(1+.00388T)}}$ but for copper 98% conductivity, $R = 1.65 \times 10^{-8}$. Simplifying for bright wire $m=1$ $C = 28.9d\sqrt{\frac{570QR_t + t}{1+.00388T}}$ where $Q = \pi d$ or the circumference.

In the case of wires suspended

freely in air the condition of heat developed, and radiation is the same, but the convection is largely increased by the movement of the air. In this case, instead of $.00175^{t}$ it is $.013d$ watts per linear cm. per $0°C$ of elevation. Modifying the previous formulae, we have

$$c = .886\, d \sqrt{\frac{d(m R_t + .013t + .00175t}{Y(1+.00388T)}}$$

Simplifying for bright ~~(wire)~~ copper $m=1$; $c = 2.89 \sqrt{\dfrac{570 Q R_t + 7.4dt + t}{1+.00388T}}$

and for blackened copper: $m=2$, $c = 28.9d \sqrt{\dfrac{1140 Q R_t + 7.4dt + t}{1+.00388T}}$

These formulae may be all easily reduced to inches and Fahrenheit and expressed in terms of d instead of c and may be much simplified by the insertion of definite values for t and T.

These formulae are to be used in (62)
determining whether a conductor which consumes the amount of energy we are willing to allow to be lost in overcoming the resistance of the line is of sufficient area to carry the required current without overheating.

Note: When the conductor indicated by the loss of E. M. F. is but slightly too small for carrying the required current, the heating may often be brought within bounds by subdividing the circuit.

Financial Conditions—

The third element in determining the loss of current allowable is the financial economy of the line. The elements involved are:—

1) The rate of interest to be charged on the capital outlay.

2) The cost of one horse power hour (13)
at the point of distribution from which
the lines are calculated.
3) The number of hours the maximum
energy is required and the number
of hours that 3/4, 1/2 and 1/4 are
required.
4) The cost of a unit weight of con-
ducting material.
5) The cost of insulation
6) The cost of line construction — as
of poles, brackets, cross arms, pins,
and insulators of an overhead wire,
or of conduits, manholes, distribut-
ing boxes etc. for an underground
line.
7) The cost of labor of placing the wire
or cables.

Now we see that since the loss
of energy may be reduced by increas-
ing the areas of the conductors

which reduces the value of R in the equation $E = C^2R$. But to do this we must increase the weight of copper in our line, as well as the amount of insulation, both of which items increases the first cost of the line construction, and for any line are problem becomes one in which we are required to find the conductors in which the total amount of energy lost and the interest one the plant becomes a minimum. That it was possible to obtain a minimum value for this sum of losses was pointed out by Lold Kelvin in a paper read before the British Association in 1881.

Let W = annual cost of waste energy
R = resistance
t = number hours per annum C flows
w = cost of one watt hour.

l = length

a = area

p = interest and depreciation rate on capital. K = capital outlay on conductors

Then the capital outlay K = the weight la multiplied by a constant k cents per pound of conductor, or $K = kla$. The annual expenditure for interest and depreciation is $pK = pkla$. The total energy being equal to C^2R, then the annual cost of lost energy W will be equal to the energy lost C^2R times the number of hours c that the current is flowing t times the cost w of one watt-hour, or, $W = C^2Rwt$, or, since $R = \frac{lA}{a}$ where A is a constant depending on the specific resistance of the conducting material $W = C\frac{^2twAl}{a}$.

Now since the total annual outlay is the sum of these two losses, we

have as the total cost of the line losses, $pK + W = pk\,la + C^2\frac{btwAL}{a}$; this will be a minimum when $\frac{d(pkla)}{da} + \frac{d(C^2\frac{twAl}{a})}{da} = 0$ which gives

$$pkl - \frac{C^2twAl}{a^2} = 0, \text{ or } pk\,al = \frac{C^2twAL}{a}$$

$\therefore a = c\sqrt{\frac{twA}{pk}}$ which is to say that the annual cost of waste energy should equal charge for interest and depreciation on the conductor.

This solution refers to a case in which the cost of the conductor is directly proportional to its weight and in which a constant current is flowing. But as the cost of line construction is made up of —

cost of conductor
cost of insulator
cost of supports
cost of placing the conductors

for a more general solution we must divide the capital outlay into two

parts, one of which will be constant (67)
for all sizes of conductors within the
limit of possible variation of size
for any one line and the other ele-
ment of cost proportional to the area
of a conductor, in which case the
capital outlay will be $K = l(ka + B)$
or the annual cost for interest and
depreciation.

$pK = plka + plB$ where B is the
constant portion of the cost of the line
construction. But since the differ-
ential coefficient of $\frac{d\,p\,l\,B}{da} = 0$
$\frac{d\,pK}{da} + \frac{dW}{da} = 0$ will be a minimum
as before when $plk - \frac{c^2 t w A l}{a^2} = 0$ or
$a = c\sqrt{\frac{twA}{pk}}$ which alters the law to
state that the most economical size
of a conductor is that in which the
annual cost of waste energy is equal
to the annual interest charge on that
portion of the line construction

[illegible]

[illegible] constructions [illegible]

[illegible]

[illegible] of the [illegible]

which is proportional to the area of the conductor.

Where the current is a variable one, we must take a value of c which will represent a current equivalent to the various increments of current for the time which they are flowing. If the total time, $t = t_1 + t_2 + t_3 + \text{-----} + t_n$ and during each of these increments of time a current represented by $c_1\ c_2\ c_3 \text{----} c_n$ is flowing, then the total waste $C^2Rt = R(c_1^2 t_1 + c_2^2 t_2 + c_3^2 t_3 + \text{-----} + c_n^2 t_n$. Therefore as

$$C = \sqrt{\frac{e}{Rt}} = \sqrt{\frac{C^2Rt}{Rt}}$$

$$C = \sqrt{\frac{R(c_1^2 t_1 + c_2^2 t_2 + c_3^2 t_3 + \text{-----} c_n^2 t_n)}{R(t_1 + t_2 + t_3 + \text{--------} + t_n)}}$$

which equivalent value of c is to be used in the equation for determining the most economical size of conductor.

The expression $K = l(Ka + B)$ for the

cost of construction may be further modified by the consideration that there are elements depending on the area of the conductor, and constant elements in the value of both the conductor and its supports, and the complete expression is, therefore, $K = l[(k_c a + B_c) + k_s a + B_s] = l[(k_c + k_s)a + (B_c + B_s)]$ which is thus stated a complete expression for K where the suffixes c and s refer to the conductor and its supports.

As may be readily seen, these three methods of determining the loss of energy allowable may not be all together used in the correct determination of a line, but each has its special application. The general principal may be laid down however, that the carrying capacity of a wire should never be exceeded

and that the consideration of
financial economy should be taken into account where they do not transgress the requirements for even distribution as is always the case when calculating a long Distance line and generally in the mains and feeders of a station.

Estimation of length.—

Finally, in our calculations of the sizes of wire for transmitting any any given current, we have to determine the length of the circuit. This depends upon the system adopted and the arrangements of the wires. Systems may be divided into two general classes, 1st, when the translating devices are arranged in series, in which case the length is at once given by a measurement of the circuit.

2nd, when the translating devices

are arranged in multiple arc, here (71)
the length of the circuit becomes a
question of distribution, which is to
say, that the circuits are to be so
arranged, as to deliver the same
amount of E. M. F. at each translating
device, lamp or motor in the circuit.
To accomplish, the circuit is divided into several sections and each
section treated separately.

Starting from the dynamo, the wires
always lead out to some distance before the lamps are applied, and after
this point, the lights are taken off
either in groups or singly.

If the entire capacity is taken off
the machine in one group, the
mains are calculated to the beginning of the group on the question
of economy of capital and the E. M. F.
at the point of distribution main-

tained constant. From that point (72)
further calculations are made of the wires for the separate devices.

Should there be a number of groups some one central point of distribution is chosen which is as near as possible the average distance from the machine, and there the potential kept constant. From the machine to whatever central distribution point is chosen, the calculations are always made on consideration of economy, since the distribution at the lights is independent of the loss in the line to that point.

The dynamo machine can only control the E. M. F at one point of the line, and though this point may be chosen at either the machine or anywhere on the line, yet from that point the arrangement

of the circuit and size of the wire is responsible for the distribution.

Two cases of distribution are presented.

1st) where the lights are either all on or all off together.

2nd. where each lamp is independent of the others. This latter case is the more difficult and the solution for it more general since its solution always solves the first case, though the solution of the first case may not solve the other.

Taking the first case we at once see that for its complete solution it is necessary that the resistance of the wire from the distributing point must be the same for each lamp.

With two wires run out parallel

this can never be the case and if it is not possible to accomplish the wiring with only a negligable difference of E. M. F. between different lamps some other method must be adopted.

A general rule to be adople is that the P. D. be not greater than two volts between any two lamps. Even this is often excessive and one volt should be aimed at.

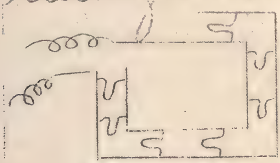
What the size wire to accomplish this is calculated as above described $d^2 = \frac{\text{total c} \times \text{L of line} \times A}{E \times n\% \text{ of total } E}$

or in this case $d^2 = \frac{\text{total c} \times \text{L of line} \times A}{2 \text{ or } 1}$

When the distance between the lights and their number make the wire too expensive to accomplish this, then special methods of wiring are to be used. Either the

complete ring

with the wires joined on opposite sides of two circles or rectangles



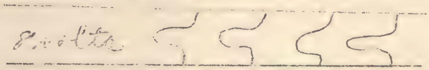
which gives exactly the same length circuit for each lamp.

For the second case where the lamps are independent of each other, the ideal system is that each lamp should have a separate pair of leads from the distributing point.

This ideal system is only rarely attainable in practice but the nearer our practice approaches such a system, the better the distribution. Hence for a good distributor, the major part of the loss of voltage from the lamps to the distributing point should be in the leads which are independent.

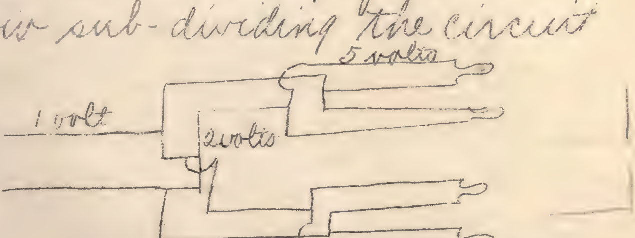
To accomplish this, sub-distrib-
uting points are to be chosen and
the wire calculated from one dis-
tributing point to another, allowing
a varying loss in each sec-
tion which increases as we go to-
wards the lamp.

Take the extreme case of four
lamps with 8 volts loss from the
distributing point.



bunched together if three are turned
off the amount is one $\frac{1}{4}$ and the loss
two volts instead of eight, an in-
crease at the lamp of 6 volts.

Now sub-dividing the circuit



giving to first distributing point
1 volt loss, to the second terminal
points 2 volts loss, from the second
5 volts loss; then the loss
for each lamp will be eight volts
as before, and if 3 lamps are turned
off the loss becomes

from 2nd	5 volts
from 1st to 2nd	1 volt
from 1st	1/4 volt
	6 1/4

or only an increase of 1 3/4 volts as
against 6 volts increase in the other
case. Hence the length for the cal-
culation of a line depends on the
distributing points taken.

For wiring the interior of a building,
these distributing points are deter-
mined by the system of wiring
adopted, which may be on the
Tree system, in which case a fair

of wires called risers are carried from the point where the wires enter the house to the top of the building with branches leading off at each floor to the separate rooms. In this case the risers would be calculated to give a small loss from floor to floor and from there would be carried branches to the separate rooms around which the circuit may be best carried in a complete circle from which the branches to the several lights in the room.

It may always be possible to reduce to a very low limit the loss of E.M.F. between the various lights and so to approach nearly to a perfect system; but we should not lose sight of the commercial side of the system, and, therefore, it is the best engineering to adopt some ra-

riation and so calculate our line (79)
that the variation in E. M. F. should
not exceed this maximum.

Wiring for house to house distribution from a central station, or, wiring of large number of lights for an office building is carried on in a different manner.

In this case two sets of wires are run; the first called the "distributing mains" and the latter the feeders.

Mains run from the dynamos over the entire system, and the feeders run direct without branching for lights, to various points on the mains.

In calculating such a system, it is necessary to lay out the circuit and location of the lights

From this some average point of

distribution is determined which gives the length of the main feeder to be used. In calculating its size this length is used, in connection with the fall of E.M.F. allowable if the lamps are near the dynamo and the main laid for its whole length of this size.

If the first lamp is near the dynamo, the main is calculated only throughout the lighting district and for such a size as will allow only a maximum variation in the E.M.F. at the various lamps.

After the maine has been calculated on either of these methods, then in order to keep the E.M.F. along it at constant figure, there are led separate feeders from the dynamo to various points along its length, which points are determined by the loca-

tion of groups of lights. From each (81)
one of such points potential wires
are led back to the power house, and
and the feeder switched in as the po-
tential in the mains falls to re-
quire it.

Line Construction and Maintenance.

Lines may be

1-Pole lines { (a) through open country
b) along railroads
c) Through tunnels

2 Underground { (a) buried
(b) in conductors

In military telegraphs of the continent some lines across the country are buried, and though this has been proposed between New York and Philadelphia, yet no long distance underground construction has been attempted in this country, partially on account of the extra cost

Location — Surveys are not frequently made for a pole line, but an exploring party sent over the country to make notes of the variations of levels and character of soil in which poles are to placed. (83)

In the case where a line runs along a railroad, the question of right of way is at once settled by an arrangement with the railroad company; but in a case where the lines runs across the country or along a public road, an arrangement must be entered into, with each of the property owners along the line.

Lines have been built regardless of opposition, and poles and lines erected by stealth, but always an ultimate cost greater than would have been incurred by purchasing the whole right of way.

The policy of the American Bell (87)
Telephone Co. is to draw up a form of agreement, which is a contract stating the probable location of the poles on a man's premises, and granting the rights of guying to trees and trimming where necessary.

The matter of trimming is a serious one as regarding a constant expenditure, and should be avoided when possible. This can be done by either erecting tall poles, or crossing from one side of the road to the other where rows of trees are encountered.

After the right of way is obtained an approximate measurement of the length of the line is obtained, and location of the poles givens with a description of the ground given, and where any variation is required, the length of the poles.

In going up and down hill, poles are so proportioned as to keep the tops as near the line of the natural curve of the wire as possible. In this way no up or down strain is applied to the cross arms. Poles are also varied in length to allow for going over trees and for crossing over other lines where necessary.

The standard length pole for telegraph and electric light service in this country and most of Europe is 35 feet set in the ground from 4 to 5 feet, depending on the condition of the soil, and carrying not over four cross-arms generally three ten pin arms.

The engineers of the telephone company have adopted a standard length of pole of 35 feet and set 6 feet in the ground, which makes it easier

for [redacted] to run over trees and other lines, to get out of the way of induction and reduce the capacity.

When these poles are naturally grown, i.e. not sawn, they should be not less than six inches at the top, specified seven, winter felled and barked.

The wood used is either chestnut, cedar, spruce, pine or fir. The best of these on account of strength and endurance, are white cedar and chestnut.

In California it is not easy to secure these nature grown poles, and sawn redwood is generally used and has given good satisfaction. These poles are sawn 6" square at top and 9" at bottom.

Before the poles are set, gains or notches are cut for the cross arms 8" from the top of the pole and 24" apart. These gains on round poles

are 3" deep and on square poles 1".

In damp climates the poles after natural seasoning are saturated with creasote oil obtained from coal tar which should be applied by some process which does not heat the wood above 212° F., preferably 150° F. In a dry climate as in California it is only necessary to dry the pole during the summer and then immerse the end of the pole which is to go into the ground in hot coal tar. Paraffine paint has also been used but is no better than coal tar and is more expensive.

Redwood poles treated with coal tar in this manner will last in this climate for 15 years, and along the U. P. a pole line exists which has been standing 35 years and is stated to be good for 10 years more.

The cross arms are of Oregon Pine (88)
sawn to 4¼" × 3¼" with holes bored for pins 12" between centres with the two centre pins next the pole 15" between centres. Before erection, the cross-arms are painted with a mineral preservative paint, which should be thoroughly applied with a brush, in two coats, rather than by dipping, as the brush method makes a more continuous coat.

Cross arms are secured to the poles by two or three Fetter drive screws driven in diagonally. In the case of the H.Y. & C long distance telephone line, the poles are bored and the arms are bolted on.

The arms are set alternately, back together and faces together so that in case of any accident pulling off a single arm, only one other

can possibly follow it, whereas, if they were all on one side, the whole line might go.

Pins are of locust or oak, or in some cases iron for strength. Oak pins are the cheapest, being turned out in large quantities by wagon factories from short pieces. Wooden pins are $1\frac{1}{2}$" in diameter and set in the cross arms before erection. Generally they are painted to correspond with the cross-arms; but a better method is to thoroughly coat them with an insulating paint such as the paraffine paint.

Where strong pins are required to go around corners etc., they may be bored and an iron bolt run through. Iron pins are $\frac{1}{2}$" or $\frac{5}{8}$" in diameter driven firmly into the cross arms, but not bolted. In such a case, a cushion must be provided for the insulator in order that

shocks against the iron will not break it.

First a wrapping of jute used, but did not hold the insulator firmly. A wooden top is sometimes used. In England, the insulator is cemented to the pin. The Klein pin with a lead top is used on this coast very generally.

The stability of a line depends:

1st Strength of wire
2nd Strain on wire
3rd Weight of wire
4th Wind pressure against wire
5th Strength of poles to resist crushing and side pressure
6th Strength of arms to carry weight.

As has been already stated, the strength of iron wire must be three times its weight per mile, which is 15840 times its weight per foot.

Strength of copper is about 16900 times

its weight per foot.

The strain in the wires is determined by the span and the sag allowed, and is generally calculated from the equation of the parabola. Poles are set from 35 to 45 per mile, but for telegraph wires an average of 35 per mile is used, while for telephone construction an average of 40 is adopted.

The horizontal tension at the centre is expressed by:- $H = \left(\frac{y^2}{2x} + \frac{x}{6}\right) w$, and the length of the wire by:-

$$2s = 2y\left[1 + \frac{2}{3}\left(\frac{x}{y}\right)^2\right]$$ where

H = horizontal tension

$2s$ = length of wire

$y = \frac{1}{2}$ span

x = deflection

w - pressure $- \sqrt{W^2+P^2}$

The tension so given should be multiplied by weight per foot.

As regards possible straightness of line,

this gives the breaking strength of iron wire as the necessary strain of a span of 125 feet with ·001 deflection and for copper wire 135 feet with ·001 deflection.

For a span of 35 poles to the mile a deflection of ·005 per cent., the span will give a factor of safety of about 4 with iron wire, and for copper wire for a span of 40 poles to the mile the deflection may be ·004 per cent for a safety factor of 4 in case of copper wire.

Beside carrying the weight of the wire, any pole line has to withstand the pressure of the wind against the lines and the poles themselves. English practice has shown that a line calculated for a wind pressure of 18·75 lbs per sq. ft. is sufficient, since the lines are not above 20 ft from the ground on the average, and this pressure which corresponds to a wind velocity of 60 miles

an hour had proved sufficient. But
should a pole line be run through a country subject to high winds and sleet storms, it is advisable to assume a wind pressure of 30 lbs. per sq. ft.

The total pressure is calculated from regarding the wires as rectangles and taking the effective area as ½ the area of the rectangle. For the strength of a naturally grown pole, the experiments of Mr. Preece of the English Telegraph gives the breaking weight as:

$$w = K\frac{D^3}{l}, \text{ where}$$

w = Breaking weight

K = a constant = 765

l = average distance of cross arms from ground.

D = diameter at ground line.

A factor of at least 6 should be allowed in such a line, and where the strain of the wires is uneven

or constant as at terminal poles an additional strut or guy should be placed where the strain exceeds $15\frac{D^3}{l}$. These guys are placed either in the line of the poles where the strain is uneven along the line of the wires or to stubs in the ground at convenience.

LINE INSULATORS.

The insulation of a bare wire line depends upon the efficiency of the insulators, hence a considerable amount of study devoted to this portion of the construction is necessary.

In Europe porcelain insulators are used altogether while in this country glass is the only material used.

The advantages of Porcelain are:-

1st Strength
2nd Non-hygroscopic surface
3rd Appearance

but they are of greater cost than the glass ones, the advantages of which are:-

1st Cheapness
2nd Less liable to harbor bugs.

For this last reason the Bell Telephone Co. use only a white glass in-

sulator.

In general practice the great trouble with either variety is the accumulation of dirt & smoke which reduces insulation of itself and retains moisture, hence it is proposed to use an insulator without a petticoat to be frequently wiped.

The double petticoat in either glass or porcelain seems to be of doubtful value since it does not keep as dry in bad weather as a long single petticoat. This single petticoat should not be very wide open to facilitate drying, but closed as far as possible to prevent moistening in damp weather.

Porcelain knobs are unfit for use out of doors.

UNDERGROUND CONSTUCTION.

In cities it becomes often necessary to place wires underground on account of:

1st The multitude of overhead wires making a dangerous and unsightly network.

2nd The liability of a disturbance in important service due to a slight accident of falling wires of other lines.

3rd The liability of a general disturbance of all lines in heavy storms, carrying down at first weak lines and then others on which they fall.

4th The difficulty in repairing and danger to men engaged in such work on account of frequent crosses with high potential circuits.

Three general systems are used for putting down wires:- 1st Solid or built-in systems
2nd "Draw in and draw out" systems.

3rd Trench systems.

1. Solid or builtin systems are systems where either a cable is laid directly in the ground or where it is laid in a trench which is afterwards filled with pitch or some other insulating compound. Any cable which is sufficiently protected from mechanical injury may be laid directly in the ground, and such a construction is often a very satisfactory one especially in dry and sandy soils, but where the ground is damp and filled with decaying vegetation liberating vegetable acids, great care must be taken in protecting the insulation and armor of the cables against decay. The best cable for such construction is a lead encased one which has been tarred or asphalted directly on the lead and then covered with tarred jute or hemp. Such cable laying does not belong to any system and is to be used only where

there is perfect immunity from mechanical injury since a very slight blow from a pick or a spade will cut through the armor of such a cable, destroying both insulation and conductors.

For laying directly in the ground, the best cable is that manufactured by the Siemens & Halske Co. who make a cable insulated with saturated jute over which is a lead covering this again jute and upon this as a bedding an armor of hoop iron about two inches wide laid spirally and the whole well asphalted. Much of this cable has been laid abroad and found to be very desirable, the great disadvantage being the difficulty in getting up and cutting the cable when a fault develops not at a junction box.

They prefer always to lay a cable containing two conductors made concentrically and each insulated independently, both con-

ductors are stranded, the stranding of the outside conductor being equal in area to the inside one. For the laying of such a cable special jointing and junction boxes are needed since it has been proved impossible to splice a stranded cable with sleeves in the ordinary way on account of the heat necessary for sweating fast sleeves to the conductors which would tend to injure the insulation.

These junction boxes increase the first cost of the cable but decrease the cost of laying.

Similar to the Siemens Halske system is the "built in" system of the Edison Company. The conductors in this system are copper rods laid in iron pipes and kept separate by a loose wrapping of jute rope and insulated by an asphalt compound poured

into the iron pipe until it is filled.
The conductors in the two wire construction are made of segmental sections, so that when the flat sides are placed facing each other the curved faces lie in the same circle which tends to give a constant strain on the insulation in all directions
In a three wire line construction, round rods are used which give an almost equally efficient construction.
The lengths of this pipe and its contained conductors are just sufficient for a house to house distribution in a city where the lots have a twenty foot front. Connections are made in cast iron junction boxes made in two halves with necks fitting the iron pipe containing copper cable connections which are sweated to the ends of the rods projecting from the iron pipes.
After the upper half of the junction box is placed in position and bolted to the lower

section the whole is filled with asphaltum
compound poured in through a large hole
in the top section which is then closed by
an iron screw plug. Slight corners are
turned by means of ball and sockets which
are attached by clamping to the iron pipe.
"Built in" systems were more in use abroad
than in this country on account of under-
ground wires being used in small towns
where the difficulties of laying were not so
great. The Callender system of vulcanized
bitumen cables laid in an iron trough filled
with asphaltum and capped with cement,
which has proved a failure here is worked into
a complete system and used with success.
The most interesting system in use a-
broad is the Ferranti used in conveying an
alternating current at 10,000 volts from
Deptford to London a distance of 7½ miles. The
conductors are composed of copper tubes

insulated from each other by $\frac{1}{2}$" of paper soaked with ozocerite wrapped on the inner tube with the outer tube drawn down tight over it, then $\frac{1}{8}$" of paper wrapped on and an iron pipe slipped over it and wax forced in to fill the iron pipe.

These tubes are made in 20' lengths jointed by means of cutting away the iron pipe and making a male and female cone in the inside insulator then forcing the tubes together by great pressure, the connect being made by a rod in the inner tube and a sleeve over the outer tube.

In this country use is generally made of conduits, separate from the cables on the draw in and out system, the conduits may be either :-

1 – Insulating
2 – Semi-insulating
3 – Metallic

Insulating conduits are used with cables

or with bare wires drawn in and entire independence placed on the conduits.

That of the Interior Conduit & Insulation Co. laid at Minneapolis for the Street Ry. Co. is the only present example of the latter construction.

Paper tubes laid in troughs and hot asphalt poured in about them with watertight manholes formed the conduits. Bare strands the conductors hauled in and insulated with rubber tubing where they passed through the manholes.

This system has been in use for three years and with good success. The great defect being that moisture will condense from the air in the tubes and manholes and destroy the insulation.

The Dorsett & Callender-Webber conduits are made of asphaltic concrete in blocks about four feet long joined by running a mandrel through the holes in two adjacent sec-

tions and then filling in between with melted asphalt which hardens and makes a continuous circuit.

This conduit has proved a failure in this country on account of the blocks of concrete getting out of line and reducing the size of the holes, as it is sure to do unless a sure foundation is made for it.

The insulating values of these two conduits are nil, as they have failed to keep out gases, condense moisture on their inside, and require the same lead encased cables as non-insulating conduits the lead armor of which must be grounded to prevent men working on the cables from receiving static shocks.

Of the second class or semi-insulating conduits, the best is the terra or terra-cotta conduit

It is made of glazed earthenware

about 1" thick in two or more rectangular ducts 3"x4" in lengths of about 3'. These lengths are fastened together with asphalted burlaps and laid either directly in a trench on boards or preferably in a bedding of concrete 4" thick on all sides.

Such a construction is gas and water tight and makes a duct easy to draw into, and affording room for several cables in one duct.

The Valentine conduit is simply a wood box made in 12' sections of creosoted wood.

The Wyckoff conduit is made of pump logs 4"x4" with 3" round hole bored through each section about 4' long with a cup and boss on its opposite ends to permit of joining together in alignment. These logs are carefully dried & creosoted and when so treated may be expected to last for a

very long time. The advantage of this conduit is its cheapness and the ease with which cables may be drawn in, as much as 1200 feet of 2½" cable having been drawn in in Philadelphia in these ducts where not over 500 feet can be drawn in other varieties. Such a conduit is said to attack the lead of the cables but where the wood is thoroughly dried and the cable, as all modern cables should be, with 3% tin in the lead, asphalted and braided or taped, no such action is observed.

Indurated fiber conduits have been laid to a certain extent but their great cost has prohibited extensive use since without an asphalt or concrete bedding they are not sufficiently tight at the screw joints to exclude water and gases.

Cement lined pipe may be called semi-insulating though no advantage is claimed for this conduit for such a property. A sheet iron pipe is made 8' in length and lined with 5/8" pure cement capable of a certain amount of flexibility on the ball and socket principle. These ducts are laid on a bed of hydraulic cement or asphaltum concrete about 2" thick, the pipes are placed 1½" apart with concrete rammed around and over them to form a bed for the next layer which is laid in the same manner - Over all a planking 2" thick to make the trench complete and turn the picks of workmen who will dig around wood when they will go through concrete

Besides these systems which have all been more or less in practical use two

important systems have been suggested but are not yet in any considerable practical use.

The Chenoweth cement system is a means of forming a smooth cement duct. Wooden mandrels wound with a metallic tape are laid as the ducts should be placed & spaced and after cement is rammed about about them, the wooden mandrel is removed and after the cement is hardened the metallic spiral is withdrawn leaving a smooth tube in the cement.

A conduit designed by Mr Bowman of The Trenton Terra Cotta Co. consists of blocks of glazed terra-cotta about 3 feet long pierced with holes of the necessary size for cables and is designed to be laid directly in the ground. It would be difficult to turn angles with this conduit and the construction would probably prove expensive

The metallic conduits were used in New

York on the failure of the Dorsett blocks. At first attempt was made to repair the defective jointing of this system by inserting paper sleeves between the sections. No such sleeves proving capable of withstanding water attempts were made to use various metallic linings. Zinc tube with the joint rolled over proved to be capable of resisting the heat of the asphaltum concrete and the action of the gases but only small amounts of this was laid on account of the liability to damage by the workman in laying. Hence, this gave place to iron gas pipes.

More iron gas pipe conduit has been laid up to the present time than any other conduit in use.

3" lap welded black iron pipe generally laid jointed with regulation screw joints and this made water & gas tight. In the bottom of the trench a layer of concrete

2" thick on this the pipes are laid about $1\frac{1}{2}$" apart, concrete rammed around and about them till there is a layer $1\frac{1}{2}$" thick over them on which another layer of pipes is laid and so on until the requisite number of pipes are laid and the whole completed with a layer 2" of concrete and a planking. Such a conduit is only a hole through a street and a mechanical protection for the cables which must be insulated independently. When placed 4' below the surface of the street is practically indestructable and have only been injured by bars driven into the street striking square upon one of the pipes. The ease with which the pipes may be bent to pass any obstruction or crowded into a narrow trench recommends this system as one of the most satisfactory.

When laid directly in the ground cast

iron lasts so much better than wrought iron but the expense of laying 3" cast iron pipe has been found to be excessive and the use of a large pipe neccesitates for economy the drawing of too great a number of cables into one duct for the best results of convenience in handling and freedom from mechanical injury. The Johnstone conduit has been devised as a complete cast iron conduit system. The conduit itself consists of two halves with side flanges to be bolted together leaving a clear space between large enough for two rows of ducts which are made by removable iron partitions which give a clear space for drawing in cables. These sections of conduits are made 6' long and laid continuously. where it becomes necessary to make connections to make connections to a house or other supply point a section with a hole in it is used to replace

a tight section and over this hole is bolted a cap in which the joint can be made. Cast iron manholes, which are also made in sections complete the whole.

This conduit is used to a very great extent for secondary feeders in New York.

The street construction for all these various ducts is approximately the same and varies only with the conditions of the locality. When there is no danger from frost and the street traffic is light the conduits may be laid either under the sidewalks or gutters at a small depth and shallow handholes made at the street corners and feeding points for the purpose of drawing in & out and jointing cables. This is the cheapest and most convenient construction when the conditions allow it. These hand holes are about three feet square & from three to four feet deep. The ducts

being laid about 18" under the surface of the street.

Where the frost is liable to interfere with such construction and the street traffic is so heavy as to injure such shallow laid ducts, it is necessary to sink the top of the ducts to at least three feet from the surface of the ground and as it becomes necessary for the workmen to descend into the manholes in order to do any necessary work upon cables, it is therefore needful that the manholes be of sufficient size for them to do the work conveniently and expeditiously. These manholes are made of brick with cement bottoms or sometimes entirely of cement. For small cable work these should be, at least four feet square and for large cables, such as telephone cables they must be made at least six feet square, the ducts being

led in about 2' from the bottom. Manholes are placed at street corners or at distances not exceeding 500'.

The cables are furnished by the manufacturers of a sufficient length to pass from manhole to manhole, with enough extra length to allow them to be carried around the sides of the manholes and leave two feet for slack and jointing.

The cable so cut is delivered on reels with two adjacent lengths on each reel, after the ducts have been rodded and a rope passed through the cable is drawn in by the rope with a capstan set in the street or a small one with a long shaft set in the manhole.

When a cable has been so drawn in, the ends are cut open and spliced, the copper with a sleeve, the insulation with itself, and the lead with a sleeve either

copied or moulded on.

Almost all the systems in this country have been means of laying well insulated conductors but abroad a considerable attempt has been made to reproduce overhead construction in underground conduits by building trenches and laying bare strips on glass or porcelain insulators, in them.

The type of this system and the one from which the others have been copied to a greater or less extent, is that devised by R. E. Crompton.

In this system, trenches are constructed directly under the sidewalk of concrete 1:3" × 12", at every 15 yards oak baulks are set into the concrete 3"×4" clearing the bottom of the trench by ½' each baulk having its centre drilled with round holes for the insertion of the insulators.

These insulators are 3" × 1" with a groove at the top for holding the bare copper strips and corrugated at the sides for insulation.

At certain distances, up to every 100 yards in straight conducts, provision is made for stretching the conductors and keeping them off the bottom of the conduit.

At these points two baulks 4" × 4" are placed one above the other with their centres 6" apart, holes are bored in the sides of these baulks and glass insulators of the same general construction, but with round heads are inserted upon these heads bronze bridge pieces are placed bridging from an upper to a lower bauck. These bridge pieces are provided with a screw clamp to secure the strips.

The whole construction so made

is closed over the top with an iron or flagstone cover, the earth rammed down and the pavement replaced, iron covers being placed over the holes which are left at the insulation and draining baulks. When the conduit is so completed a leading string is run through by rodding or other method and copper strips 1" × $\frac{1}{4}$" led through and placed in the insulator grooves, one end is clamped and a strain put on the other end until the rods are straight and then they are clamped in place.

Interior Wiring.

House wiring may be done:-

1st On cleats or knobs

2nd In mouldings

3rd In conduits

The first method of wiring is very satisfactory from the electricians standpoint because they allow all the wires to remain permanently in sight for easy inspection and as it adds to the insulation of the wire an insulation of air: hence in mills and other buildings where there is no attempt at decoration this system of wiring is universally adopted. Used also in stores where the wiring must be cheap Such a construction is unsightly, not only on account of the position of the wires, but also because the electrified wires will collect dust and lint and

are dangerous in case of a fire hence where such wires are used, they must be frequently cleaned.

Mouldings are strips of whitewood with grooves $\frac{1}{2}$" apart and furnished with a cap to be screwed on after the wires are in place.

These are used very extensively in England even for concealed wiring. When used in any place liable to the least dampness, they should be impregnated with some compound which will saturate the wood and keep out moisture. Most of the insurance specifications require that all such mouldings be given two coats of insulating paint; this must be done before the mouldings are erected.

Such mouldings are used in buildings where the walls are

already finished and are made to correspond with the decorations as far as possible, sometimes taking the place of picture mouldings.

Where concealed work is to be done, the wires may be run behind the plaster of the walls, if a properly insulated wire is used, but such a system is not looked upon with as much favor as one in which a mechanical protection is afforded the wires by some form of conduit construction.

Such a construction is the same in theory as the underground conduits for street cables namely:— that the conduits shall be a mechanical protection for the wires and at the same time allow any withdrawal of the wires for repairs or replacement at any time.

The insurance rules in regard to such

a construction state: that the construction must be completely watertight from end to end and shall readily allow all conductors to be withdrawn without disturbing the conduit.

The "Interior" conduit system uses paper tubes, saturated with an insulating compound kept at a very high temperature. These tubes are jointed with brass collars corrugated down to make them waterproof and provided with small wood junction boxes in which may be placed cut-outs, switches joints &c.

Such a system provides a continuous watertight conduit throughout the house and when properly installed every wire is accessible without disturbing walls or flooring.

Such a conduit system is preferably

installed on the lath joists with the lathing and embedded in the plaster, when so installed it is proof against fire whether from within or without.

The American Circular Loom Co. provide a flexible conduit with a woven covering.

On account of the patent contest in regard to the system, they provide no fittings or junction boxes and all fittings etc have to be taken from some other system.

Switches.

There are a great number of various designs of switches, but all embodying the same principles as being according to use:—

1st Station switches
2nd Snap switches
3rd Short circuiting switches;

and according to their constructions

1st Single pole	Single breaks	
2nd " "	Double "	
3rd Double "	Single "	
4th " "	Double "	

Comparatively few single break switches of either single or double variety used as they necessitate either a flexible cable connection to the switch or else that the current be carried through a moving contact, which is always to be

avoided if possible. Where it is necessary the current should not be carried through the pivot or any of the switch springs but a separate contact piece provided. The object of double pole switches and cutouts is to provide against the possibility of accident from the occurence of two grounds occuring at different parts of the circuit only one side of which is protected by a single-pole device.

All switches should be:

1st On an insulating base.

2nd Mechanically strong,

3rd Points of sufficient contact area,

4th Break of sufficient length to extinguish spark,

5th Quick make and break without the possibility of slow opening in any manner.

L.S.Jr.U. December 1894.

F.V.T.LEE. Mimeo.